EIC AC LGAD R&D Proposal - eRD112

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Content

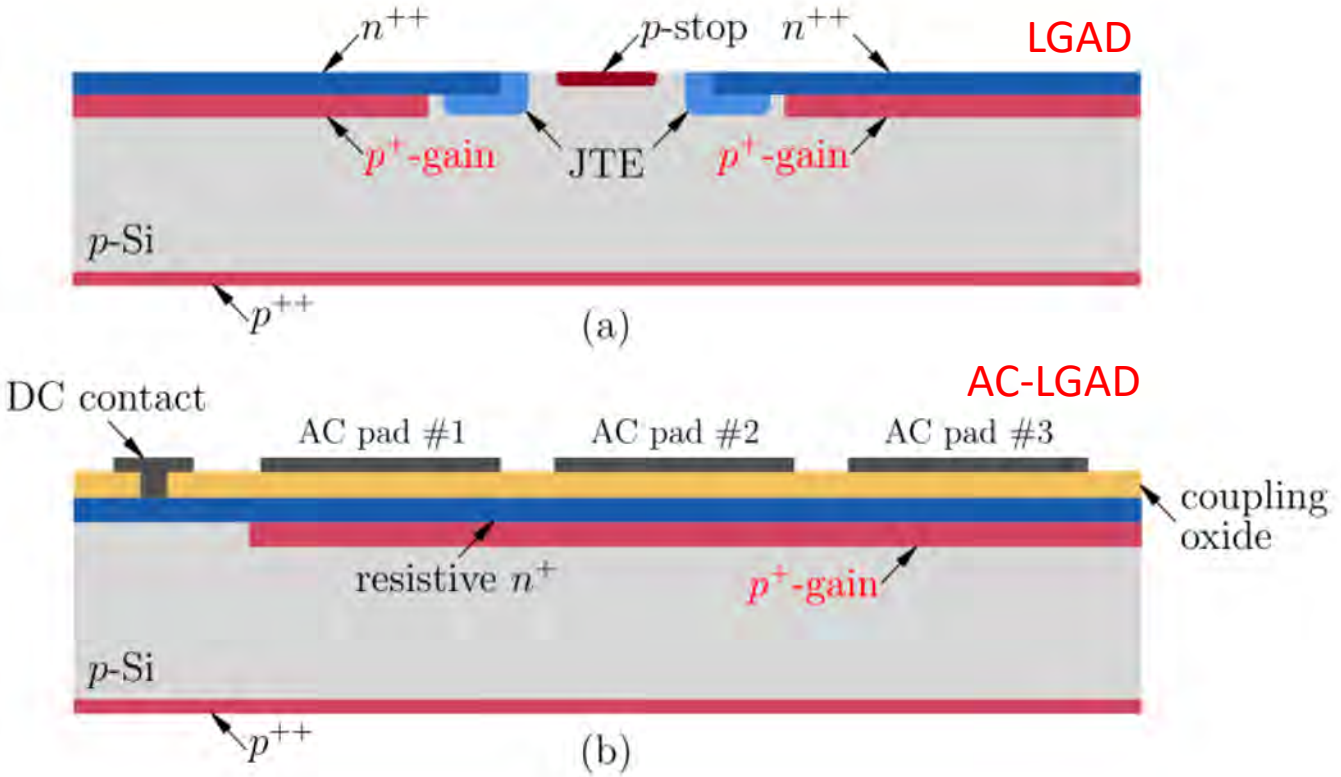
- AC LGAD for EIC
- R&D needs: Sensor, ASIC, Services
- FY22: deliverables and budgets
- FY23-26 : timeline and deliverables

AC LGAD for EIC

- Large area LGAD detectors are being built by ATLAS (6.4 m^2) and CMS (15.6 m^2) for data taking starting in 2026.

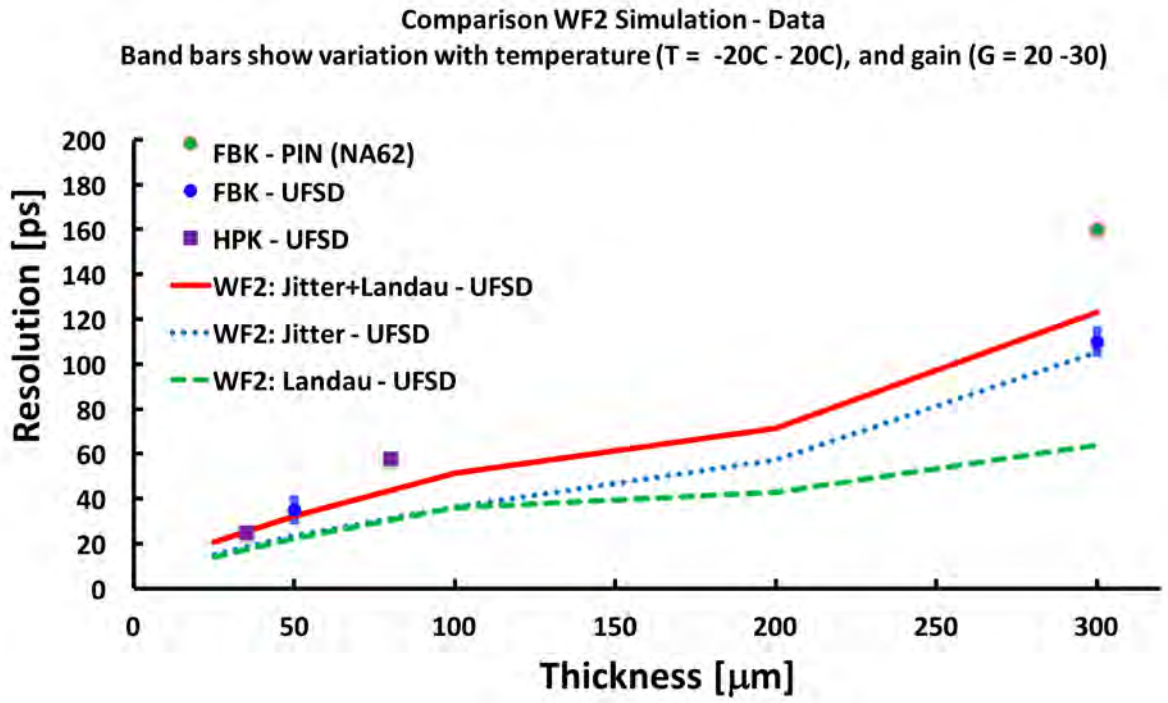
- AC LGAD detectors proposed for EIC
  - Roman Pots and B0
  - TOF for PID (and tracking)

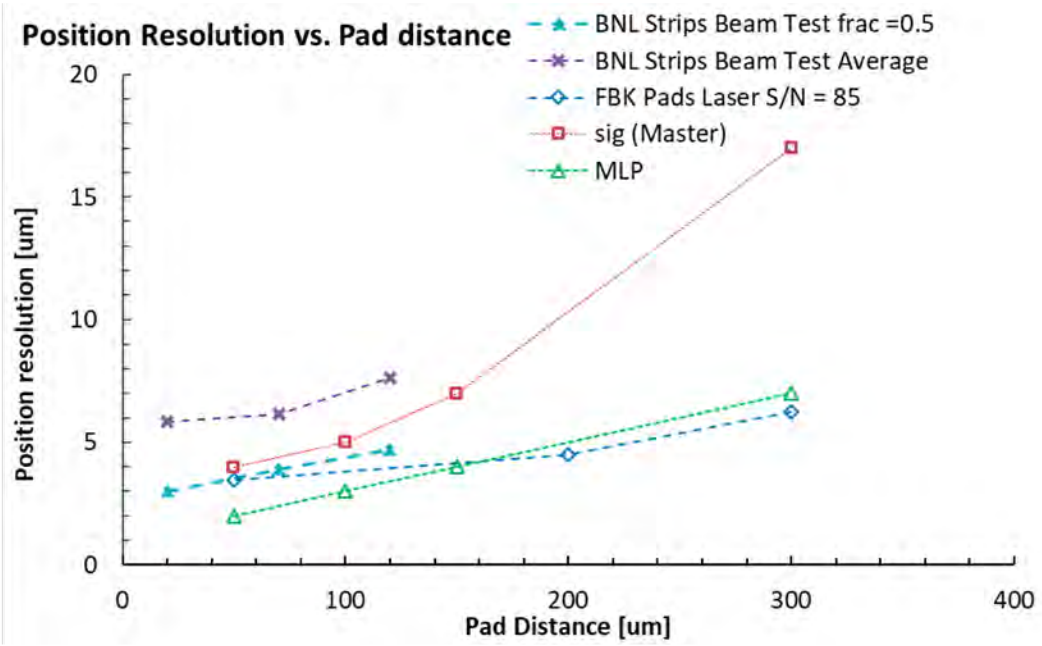
- Have common designs in sensor, ASIC etc. when possible, combine R&D efforts



	Time resolution / hit	Position resolution / hit	Material budget / layer
Barrel ToF (Tracker)	<30 ps	(3-30 μm for Tracker)	$< 0.01\ X_0$
Endcap ToF (Tracker)	<25 ps	(30-50 μm for Tracker)	e-direction $< 0.05 X_0$ h-direction $< 0.15 X_0$
Roman Pots	<50 ps	$< 500/\sqrt{12}\ \mu m$	N/A
B0	<50 ps	$O(50)\ \mu m$	$< 0.01\ X_0$

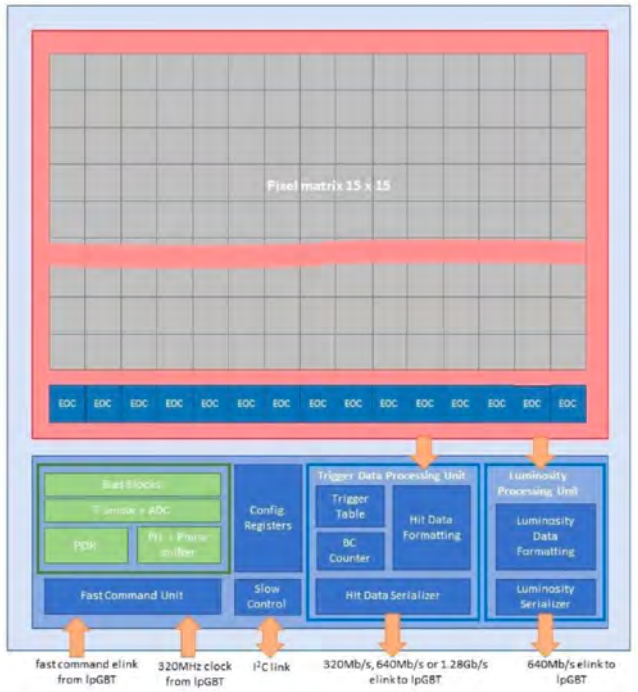
Sensor

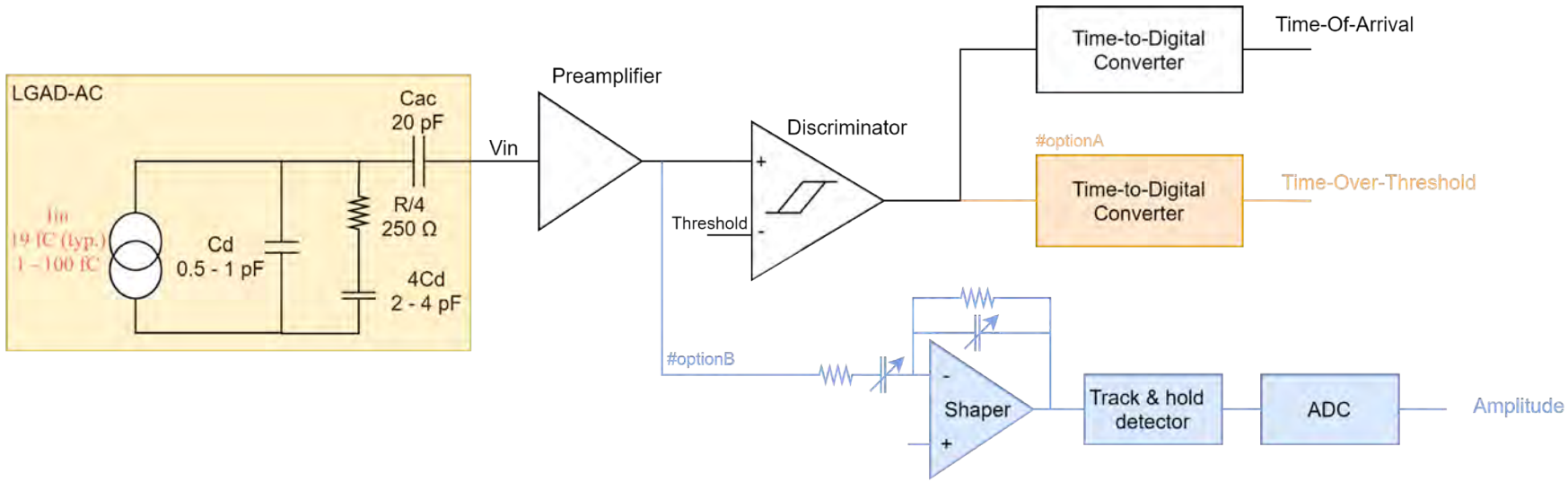




- **R&D Goals**
  - 15-20 ps timing resolution, O(3-50μm) position resolution where needed
  - Minimal readout channel density (long strip, rectangular pixel) for reduced power and thus material and cost
- **Plan**
  - Produce and test sensors with thinner active volume to achieve the desired timing resolution
  - Optimize implantation parameters and AC-pad segmentation through simulation and real device studies
  - Engage commercial vendors to improve fabrication process and yield

ASIC





- **R&D Goals**
  - 15-20 ps jitter with minimal (1-2 mW/ch) power consumption, match AC LGAD sensors for EIC
- **Plan**
  - Continue the ASIC prototyping effort for RPs by IJCLAB/Omega (1st submission in FY22 funded externally)
  - Utilize the design and experience in ASICs for fast-timing detectors from ATLAS and CMS, and investigate common ASIC design and development for RPs and ToF

FY22 Deliverables

- High-level strawman layout design and requirements for sub-systems using AC LGADs.
- Production of medium/large area sensors with different doping concentration, pitch and gap sizes between electrodes to optimize performance by BNL Instrumentation and HPK.
- Start production of sensors of small thickness (20, and 30 microns) for ToF applications with time resolution 20 ps by BNL Instrumentation.
- A first ASIC prototype that is compatible with EIC Roman Pot requirements and can read out an AC-LGAD with 500 micron pitch and 20 ps time resolution.

FY22 Budget Requests – M&S

Vendor/ Institute	M&S Item	Cost per Item [$]	N. Items	Tot. Cost [$]
BNL IO	Sensor fabrication (incl. labor)	50k (10 wafers)	1.5	75k
Hamamatsu	Sensor fabrication (incl. labor)	75-100k+3-5k/wafer	0.5	80k
IJCLAB/Omega	ASIC submission	N/A	1	0 (in-kind)
Multiple	1-4 channel fast-time test-board	100	40	4k
Multiple	Multi-channel fast-time test-board	300	20	6k
BNL	Travels to Fermilab testbeam	2k	2	4k
UIC	Travels to Fermilab testbeam	1k	2×2	4k
Rice	Travels to BNL and Fermilab	3k	2	4k
UCSC	Travels to Fermilab	3k	1	3k
TOT.				**180k**

FY22 Budget Requests – Labor

Inst.	Task	Labor Type	FTEs [%]	Cost [$]
Multiple	Testboard part assembly and testing	El. Tech.	10	20k
BNL	Sensor+testboard assembly (incl. wirebonds)	El. Tech.	10	20k
	Sensor dicing& testing before distribution	Tech.	15	20k
	Sensor testing	Scientists	20	0 (in-kind)
	Sensor testing	Postdocs	20	0 (in-kind)
IJCLAB/ Omega	ASIC design	Engineers	20	0 (in-kind)
	ASIC design	Scientists	90	0 (in-kind)
	ASIC design	Students	80	0 (in-kind)
UIC	Detector simulation, strip sensor device simulation and design optimization	Faculty	15	0 (in-kind)
	Strip sensor dicing & testing before assembly	Tech./Stud.	15	15k
	Sensor+testboard assembly (incl. wirebonds)	El. Tech.	10	15k
	Detector simu., sensor bench/testbeam test	Postdoc/Sp.	50	45k
Rice	Detector simulation	Faculty	10	0 (in-kind)
	Pixel sensor testing, thin sensor optimization	Postdoc	50	50k
	Sensor testing	Students	20	0 (in-kind)
UCSC	General oversight, data analysis	Faculty	10	0 (in-kind)
	Testbeam operations, data analysis	Postdocs	10	0 (in-kind)
	Testbeam apparatus design and production, sensor testing	Specialists	15	32k
	Test beam execution, data analysis	Students	15	4k
LANL		Scientists	20	0 (in-kind)
		Postdocs	20	15k
TOT.				**236k**

FY23-26 Deliverables and Milestones

FY23

- Sensor prototype with 30 ps time and space resolution match RPs and Tracker;
  Sensor prototype with 20 ps time resolution for ToF
- 1st sensor + ASIC demonstrator for EIC applications and testing with particle beam.
- 2nd ASIC prototype submission with better performance and extended features.
- Irradiation campaign for sensor and ASIC prototypes.
- Development of cooling strategy and mechanical requirements.

FY24

- Optimized AC-LGAD sensor layouts and performance.
- 3rd ASIC submission, aiming to match ToF timing requirements.
- Definition of cooling strategy and mechanical design.
- Design of flexes, interconnects and off-detector electronics.

Sensor **ASIC** **Prototype Module** **Services**

FY23-26 Deliverables and Milestones

FY25

- Sensor fabrication with expected module-size and target time and space performance.
- 1st full-scale ASIC submission.
- 2nd sensor+ASIC demonstrator with second generation parts, testing with beam.
- Irradiation campaign for sensor and ASIC prototypes.
- Cooling strategy demonstration.
- Prototyping of flexes, interconnects and off-detector electronics.

FY26

- 2nd (and last) full-scale ASIC submission with optimized design.
- 3rd demonstrator of module with optimized sensor, ASICs, prototype interconnect and cooling

Sensor **ASIC** **Prototype Module** **Services**